WINDROWER and HARVESTER for TUNG FRUIT

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Windrower and Harvester for Tung Fruit

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Tung oil is widely used in the manufacture of paints and varnishes for protecting both wood and metal surfaces. It is a rapid-drying oil and has the special quality for developing a hard, smooth, resinlike surface that is flexible when dry. The oil is made from the fruit of tung trees which are grown in a belt approximately 100 miles wide extending along the Gulf of Mexico, from Louisiana through Mississippi, Alabama, Georgia, and Florida. Tung was introduced commercially in the United States in the early 1930's and had expanded to about 200,000 acres before hurricane Camille (August 17, 1969), with some of the original plantings still in production.

Tree spacing and row width vary considerably throughout the growing area. The number of trees planted per acre may vary from 75 to 140, 10 to 20 feet apart in rows 25 to 35 feet apart. The most recent plantings are 10 to 12 feet apart in rows 32 feet apart. Since the trees are grown in an area of high rainfall and rolling terrain, most of the trees are planted in contoured rows in terraced fields.

Some varieties of tung trees are poorly shaped and the limbs are easily broken. Branches close to the ground are subject to breakage by the machines used in the various cultural operations.

Depending upon variety, age, soil type, cultivation, fertilization, orchard site, and tree population, yield may vary from 1 ton to 3 tons per acre. Tung is deciduous, but usually the leaves do not fall until after a freeze. In a normal year most, but not all, of the fruit falls before the leaves drop. The large tung leaves then fall on the fruit and form a thick mat. The leaves are picked up with the fruit and separated by the harvester.

The hulls, which surround the segmented tung fruit, have some fertilizer value, analyzing about 0.60 percent nitrogen, 0.30 percent phosphate, and 2.5 percent potash. Tung press-cake meal, one of the principal byproducts of tung oil processing, contains 4 percent nitrogen (equivalent to about 27 percent crude protein), 1.3 percent phosphorus, and 2.7 percent potassium. Although this is a high protein meal, it is unsuited for use as livestock feed without additional processing.

HAND HARVESTING TUNG FRUIT

The general practice of harvesting tung consists of hand picking fruit from the ground after it has matured and dropped. The unhulled fruit is gathered in baskets, then dumped into burlap sacks. The filled sacks are placed in the crotch of the tree for air drying. After the fruit is air dried, hand labor is used to remove the sacks and empty them into trucks for transporting to the processing plants.

Hand harvesting generally consists of two pickings. The first picking takes place when the majority of the fruit has fallen, but before many of the leaves come down. During this period the fruit is easy to find and can be gathered more easily. The last picking takes place after all the fruit has fallen and is customarily referred to as "scrapping." Hand gathering from the ground is slowed consid-

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erably once the leaves have fallen. As much as 15 to 20 percent of the fruit may be left on the ground, hidden by the leaves.

Hand pickers gather an average of 5 to 6 bushels of tung fruit per hour when yields are good and when the ground beneath the trees is free of briars and other weeds.

Once tung fruit falls to the ground and has cured (sap moisture dried out), it should be harvested as quickly as possible to minimize the damage caused by wet weather. Tung fruit that falls onto freshly cultivated or wet ground becomes partially embedded in the soil and is difficult to pick up. Harvesting tung by machine can shorten the time required to bring in the crop and thereby minimize the weather hazards.

The major expense in tung production is the harvesting and handling of the crop. Hand harvesting and placing the fruit into a transport truck costs from $25 to $35 per ton. The cost of harvesting with a mechanical harvester on a "custom" basis varies from $20 to $25 per ton. Variation in the cost per ton depends on yield per acre and orchard condition.

MACHINE HARVESTING TUNG FRUIT

In preparation for mechanical harvesting, the ground in the orchard should be leveled—after the last recommended cultivation—with a chain link harrow, a standard spike tooth harrow, or a heavy cylindrical roller. Before harvesting is begun, large limbs which have broken and fallen to the ground must be removed.

Mechanical harvesting of the tung fruit is done in two operations with two similar machines, a windrower and a harvester. Windrowing the tung fruit is recommended to obtain greater efficiency of the harvesting machine.

The harvester picks up the fruit directly from the ground, but it cannot operate as close to the trees as the windrower, and sometimes the variation of space between the tree rows causes the harvester to miss some fruit. When all the fruit on each side of the tree row is in one windrow the harvester will then work nearer its capacity and more efficiently most of the time.

Description of the Windrower

The windrower consists of a rake mounted in front of a specially built, small, three-wheeled tractor. Figure 1 shows a general view of the left side of the windrower. Figure 2 shows a general view of the right side of the windrower.

The raking element of the windrower is a standard 24-inch-diameter, double-conveyor screw cut down to 20 inches. The overall length is 7 feet. A flat steel band, ⅛ inch by 2 inches and with ⅞-inch-diameter holes punched or drilled in it, is welded to the outside edge of each conveyor flight. The center distance between the holes in the band is 1¼ inches and the center line of the holes is seven-eighths of an inch from the edge of the band. Forming the band to fit when it is being welded to the flight is important.

Slightly tapered and semirigid rubber fingers, 5 inches long, are inserted into every other hole in the steel band (around each flight in the raking element) and are held in place by a groove around the base of each finger. More flexible rubber fingers, 10 inches long, are inserted between the short, semirigid fingers. The

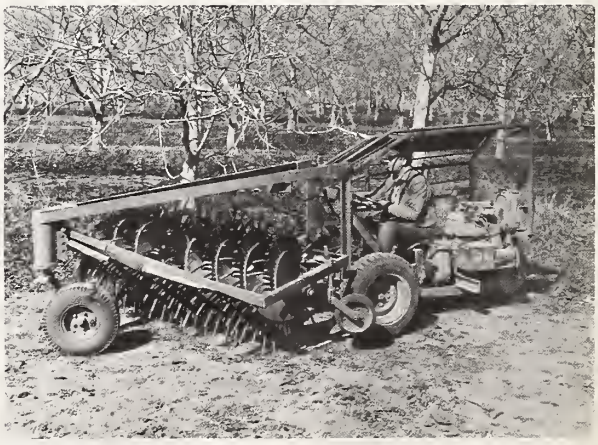

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Figure 1.—The left side of the self-propelled windrower, showing the supporting frame for the raking element. The small wheel at the discharge end of the rake gages the depth at which the rake operates.

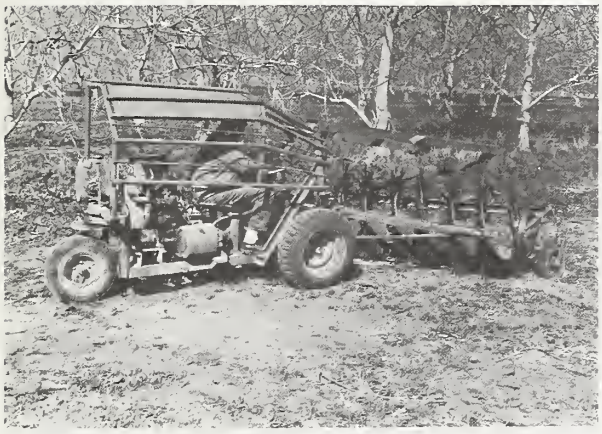

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Figure 2.—The right side of the windrower showing, the power drive to the end of the rake, stabilizer bar for maintaining rake angularity, self-contained hydraulic power unit, and shield for protecting the operator.

short fingers penetrate the soil about half an inch deep and move the tung fruit and other material toward the discharge end of the rake. The primary purpose of the longer and more flexible rubber finger is to follow the small irregularities and depressions in the soil surface. As a result, the raking element moves more tung fruit into the windrow.

The effective diameter of the raking element varies from 30 inches to 40 inches. The difference in the diameter is due to the 5- and 10-inch rubber fingers.

The discharge of a standard pitch screw conveyor (without a stationary trough) when moving with respect to the ground is a function of the diameter, revolutions per minute (r.p.m.), the angle to the forward travel, and the forward speed of the tractor.

To operate successfully in a tung orchard yielding 2 tons per acre and when all the leaves are down, the angle of the raking element must be 65° to the forward travel.

The suspension system for the raking element is simple and very effective in providing freedom of movement. The supporting frame, as shown in figure 1, is attached to the tractor at two points and is free to move in a vertical plane. The extreme forward end of the supporting frame is carried by a caster wheel.

The position of the raking element with respect to the ground is maintained by a stabilizer bar that is attached to the tractor and the raking element frame.

An 18-horsepower (hp.) or greater power unit is sufficient for the windrower under normal field operating conditions. Power is transmitted to the raking element from the drive shaft of the tractor through two sets of roller chain sprockets, three 25-hp. universal joints, and a sliding jaw clutch. This method of power transmission works very well because the speed of the raking element is in constant ratio to the forward speed of the tractor—1 revolution to 2.5 feet traveled.

The raking element, which has a clearance of 10 inches, is lifted hydraulically with one cylinder. Hydraulic power for moving the cylinder is provided by a self-contained pump. A shield on the tractor lifts the low tree branches and allows them to slide over the equipment with a minimum of breakage to the tree. It also protects the tractor operator. Figure 2 shows the hydraulic lift system and the shield for protecting the operator and minimizing damage to tree limbs.

In some instances, this type of raking element has been mounted in front of a standard 35-hp. tractor, and a jackshaft is used to transmit the power from the power takeoff to the front of the tractor.

Performance

Mounting the raking element in front of the tractor provides good visibility for the operator. Figure 3 shows the windrower operating close to the tree and raking the fruit and

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Figure 3.—The windrower, operating close to the trees and raking the fruit and other material into a windrow.

other material into a windrow. The windrower is easy to maneuver so that raking can take place near the tree trunks. It also has a short turning radius so that irregular areas can be easily covered.

Availability

At the present time the windrower is not being built commercially. However, the machine is relatively simple and can be constructed in any well-equipped shop. Basic and critical dimensions are shown in a line sketch in figure 4.

Description of the Harvester

The tung harvester picks up the windrow of tung fruit, leaves, twigs, sticks, and some soil. The leaves, small twigs, and fine particles of soil are separated from the fruit by a blast of air from a fan mounted on the machine. The heavier particles of soil are sifted through a perforated metal belt conveyor. The large sticks are removed by a stick removing device.

The clean fruit is placed in a wirebound, wooden pallet box which is carried on forks on the rear of the harvester. The box has a capacity of one-half ton of unhulled fruit.

Pickup Unit

The material from the windrow is actually picked by a combination of rake, sliding ground shoe, and an elevating conveyor.

The raking element is a duplicate of the one used on the tung windrower, except that the conveyor screw is tapered at the discharge end and the original screw diameter of 24 inches is used. Starting 12 inches from the discharge end, the screw diameter tapers 8½ inches per foot, making an angle of approximately 35 degrees to the central shaft of the raking element, and diminishing from 24 inches to 7 inches at the end of the screw.

The elevating conveyor is inclined approximately 35 degrees from the horizontal. The 32-inch-wide conveyor belt is made of 3-ply rubber and has rubber crossbars, 1⅛ inch high, vulcanized to it at 6-inch intervals. The lower part of the conveyor moves over a 2-inch-diameter idler roller which is supported by a sliding shoe plate.

The raking element is positioned 65 degrees to the sliding shoe and the tapered part of the rake extends beyond the edge of the shoe and onto the conveyor. This arrangement moves the windrow of tung fruit and other material over the edge of the shoe and up onto the conveyor.

The raking element has the same arrangement of rubber fingers as the windrower, except for the tapered part where all the fingers are semirigid and shortened to just clear the bars of the elevating conveyor.

The raking element, sliding ground shoe, and the (inclined) elevating conveyor are held in their relative positions by a sturdy frame. The frame is lifted by a hydraulic cylinder and suspended by cables at three points. The pickup unit, when raking, is pulled from a ballpoint hitch in front of the unit. A stabilizing bar maintains the 65-degree angle of the raking element to the tractor chassis. The unit follows the ground surface, riding on the skid shoe at the inner end and on a caster wheel at the outer end of the rake. A rotating sweeper, figure 5, in front of the sliding shoe sweeps leaves and fruit away from the sliding shoe. The sweeper is made of four equally spaced rubber belt flaps 3 inches wide and has an overall diameter of 24 inches. The speed is 70 r.p.m.

The pickup unit is mounted in front of the tractor on a frame similar to the windrower supporting frame but it is more sturdily constructed. A dual caster wheel supports the frame in front. The back of the frame is supported by two points on the tractor, thus permitting vertical movement of the frame with respect to the tractor.

Design of Tractor Unit

Many parts used to build the tractor unit were obtained from an auto salvage yard. A 1½-ton truck rear end, with a low- and high-range shift in the differential, equipped with dual 9.00 by 20 tires, a five-speed transmission, and a standard ½-ton pickup front axle were the major parts secured at the salvage yard.

A power unit, rated at 40 hp. at 2,000 r.p.m. is required. The chassis frame is fabricated with 4-inch channel. The wheel base is 118 inches. The differential must be turned over so that the eight speeds will operate in a reverse direction rather than in the normal forward direction as it was in the truck.

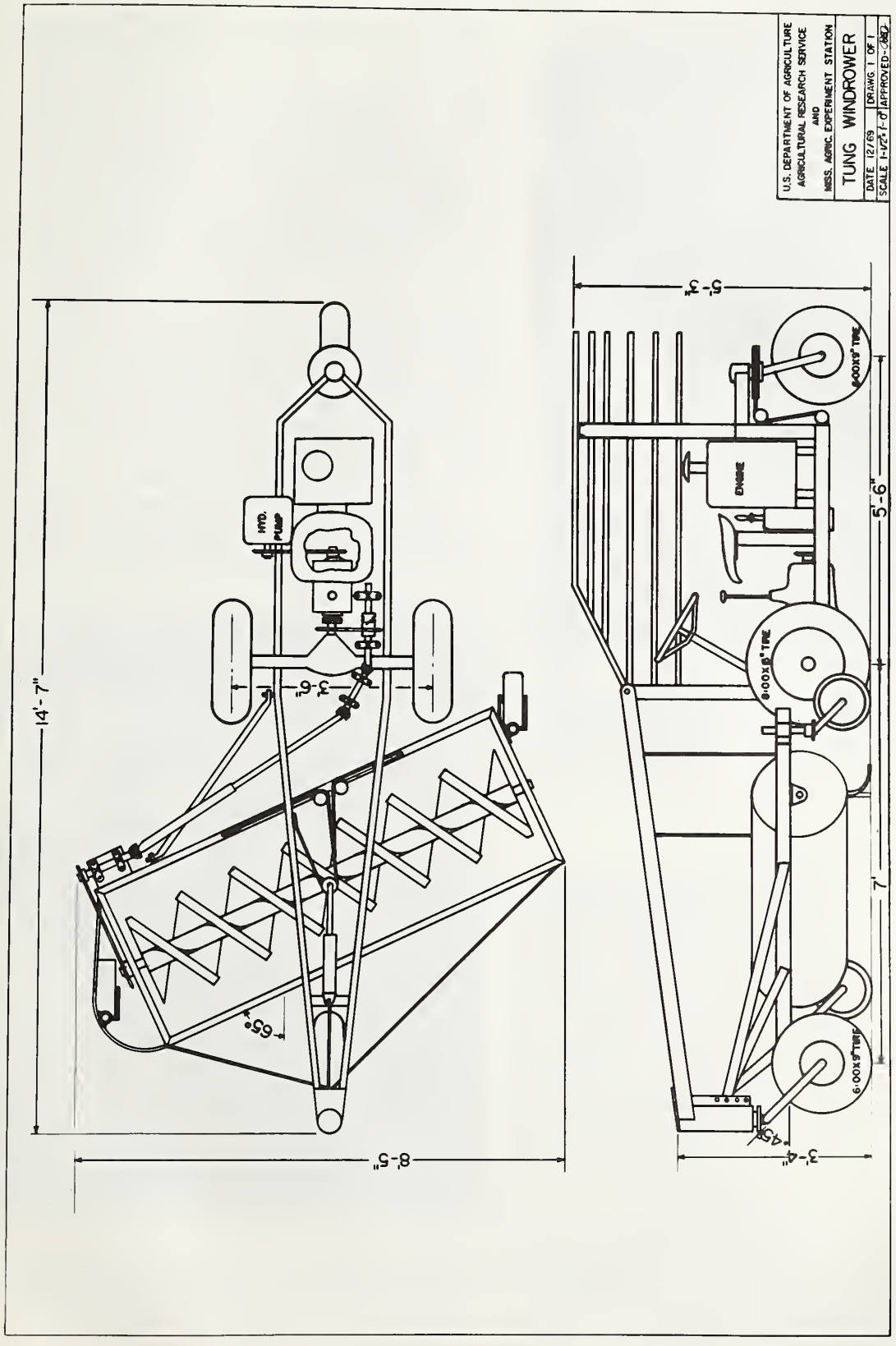

Figure 4.—Line sketch of the windrower, showing the basic dimensions and a few of the critical details.

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Figure 5.—The tung harvester picking up a windrow.

The forward speed, with an engine r.p.m. of 2,000, should range from a minimum of 0.5 mile to a maximum of 5 miles per hour. To obtain this speed range, it is necessary to calculate the sprocket ratios between the engine and the transmission. It is necessary to use a right-angle drive gearbox in order to properly position the engine on the harvester frame. The ratio of the gearbox may be used to reverse the ratio between the engine and the transmission.

Cleaning and Elevating the Harvested Tung Fruit

Harvested tung fruit is cleaned by one of the oldest and most effective principles of seed cleaning. This principle involves the passing of air through free falling material to remove the lightest particles.

The material that is picked up by the rake is dropped onto a conveyor along the side of the tractor unit as shown in figure 6. Air, blown through a specially designed orifice, is directed beneath the elevating conveyor on the rake. The orifice is 1½ inches wide and 32 inches long, with baffles that distribute the air uniformly throughout the length of the orifice.

When field conditions are normal and the fallen leaves do not contain excess moisture, air volume of 2,500 c.f.m. and 2-inch static pressure will satisfactorily remove 85 to 95 percent of the trash and immature fruit.

The side elevator is 18 inches wide and 12 feet long. A flexible, flat wire belt of ½- by ½-inch mesh conveys the tung fruit up an incline of approximately 10 degrees. The belt has no crossbars and the fruit moves satisfactorily up the elevator. The slight slipping or tumbling of the fruit on the belt removes practically all of the soil that has adhered to the fruit.

The elevator belt is driven by a solid rubber roller. The roller is made of circular sections cut from heavy rubber belting, placed on a 1-inch-diameter shaft, and compressed between two flange plates that are welded to the shaft. The distance between the plates is one-half inch greater than the width of the elevator belt.

The idler, at the opposite end of the conveyor, is a smooth steel roller with the same diameter and width as the driving roller.

Six rollers, 2 inches in diameter and with sealed ball bearings, are equally spaced to support the conveyor portion of the belt, and three

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Figure 6.—This view shows the rake, rubber belt elevator, air nozzle beneath the end of the belt elevator, and the side elevator with flexible, flat wire belt.

more support the return portion. These rollers are readily available from conveyor system manufacturers.

The rubber driving roller has greatly improved the durability and operation of the flat wire belt for this particular adaptation. Although no slippage was observed under normal operation, if the belt becomes jammed and stops, the rubber roller will continue to turn and operate as a safety slip clutch.

Stick Remover

The tung fruit and remaining leaves and sticks are dropped from the side elevator onto a stick-removing conveyor which is in line with the side elevator but at a lower elevation. Air is directed perpendicularly through the flow of material to remove foreign material. See figure 7.

The stick-removing conveyor is an open trough 18 inches wide and 4½ feet long. The bottom of the trough, into which the tung fruit and other material fall, is solid for about 2 feet and the remainder is open. A drag chain, with rubber bars attached crosswise to the chain at 5-inch intervals, moves the fruit toward the open trough. Flexible steel cable is threaded through each bar, about 5 inches from each end, making 5- by 5-inch openings between rubber bars, drag chain, and steel cable (see fig. 8).

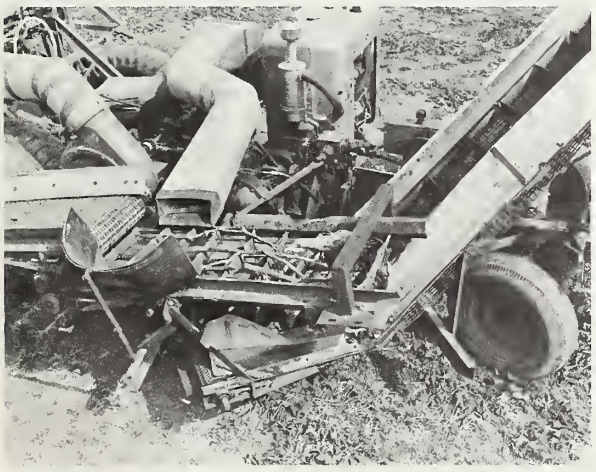

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Figure 7.—As the fruit and other material drop onto the stick remover, air is directed perpendicularly through the falling material to remove the light foreign material.

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Figure 8.—The stick remover is shown as an extension to the long side conveyor. Sticks longer than 5 inches are carried to the end and dropped to the ground. Steel cables, threaded through the rubber crossbars are used to reduce the size of the opening and are flexible enough to prevent jamming.

As the material is conveyed over the openings, sticks that remain on the top of the conveyor are dropped on the ground. The fruit, sticks, and other foreign material too small to be separated from it are dropped through the opening onto another elevator.

The fruit is then conveyed into a wirebound, wooden box which is carried on a pair of forks at the rear of the harvester. The box, 3⅛ by 3½ by 4 feet, has a volume of about 50 cubic feet and will hold about 1,000 pounds of unhulled tung fruit.

Tractor with Front-End Loader

A tractor with a front-end loader and a set of forks on the three-point hitch is used to carry boxes to and from the harvester. When the box on the harvester is filled, the forks are

lowered and the box is left on the ground. The empty box on the front-end loader is then placed on the harvester forks, and the full box is picked up by the rear forks of the loader and carried to the transport truck.

The normal lift of a front-end loader is about 10 feet. In order to gain a greater height of lift for better distribution of the fruit in the truck, a portable ramp is used. The ramp may be made from a salvaged truck frame and rear end on which are secured two plank runners. The ramp will normally add about 3 feet of height to the lift of the loader.

The tractor, with a full box on the loader and a full box on the drawbar as a counterweight, is driven up the ramp to the truck and the fruit in the elevated box is dumped into the truck. The full box on the drawbar is placed on the ground near the ramp. This box will be placed on the loader and emptied when the next full box is brought from the harvester. Fruit being dumped into a transport truck is shown in figure 9.

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Figure 9.—Portable ramp used to dump the boxes of fruit into a truck. About 3 feet of additional height is gained for the lift.

APPENDIX

Harvester Specifications

1. Self-propelled unit: Speed range 0.5 mile to 5 miles per hour.
2. Power unit: Rated 40 horsepower at 2,000 r.p.m. governed speed.
3. Raking element: Standard 24-inch pitch double-conveyor screw, 7 feet long.
4. Rubber fingers: 140 5-inch semirigid rubber fingers and 140 10-inch flexible rubber fingers are used on the raking element.
5. Speed of raking element: 1 revolution per 2.5 feet of travel.
6. Elevating belt conveyor: 32 inches wide, 3-ply rubber belt, 1-inch high rubber crossbars spaced 6 inches apart. Linear velocity 160 feet per minute.
7. Long side elevator: 18 inches wide, 180 feet per minute linear velocity.
8. Stick remover: 18 inches wide, 95 feet per minute linear velocity.
9. Elevator to box: 12 inches wide, 170 feet per minute linear velocity.
10. Skid shoe rotating sweeper: 4 equally spaced rubber belts, 3 inches wide, overall diameter 24 inches, 70 r.p.m.

Performance of Harvester

The harvester will pick up 95 to 100 percent of all material in the windrow. This includes the tung seed which sometimes become separated from the hull late in the harvest season.

The self-propelled tung harvester operates satisfactorily on contour rows on sloping hillsides.

The long flexible rubber fingers are very effective in sweeping the fruit out of small depressions.

All foreign material except very small sticks are removed by the cleaner.

Availability of Harvester

Although the harvester is not now (1970) being built commercially, it can be built in a well-equipped shop. Basic and critical dimensions are shown in figure 10.

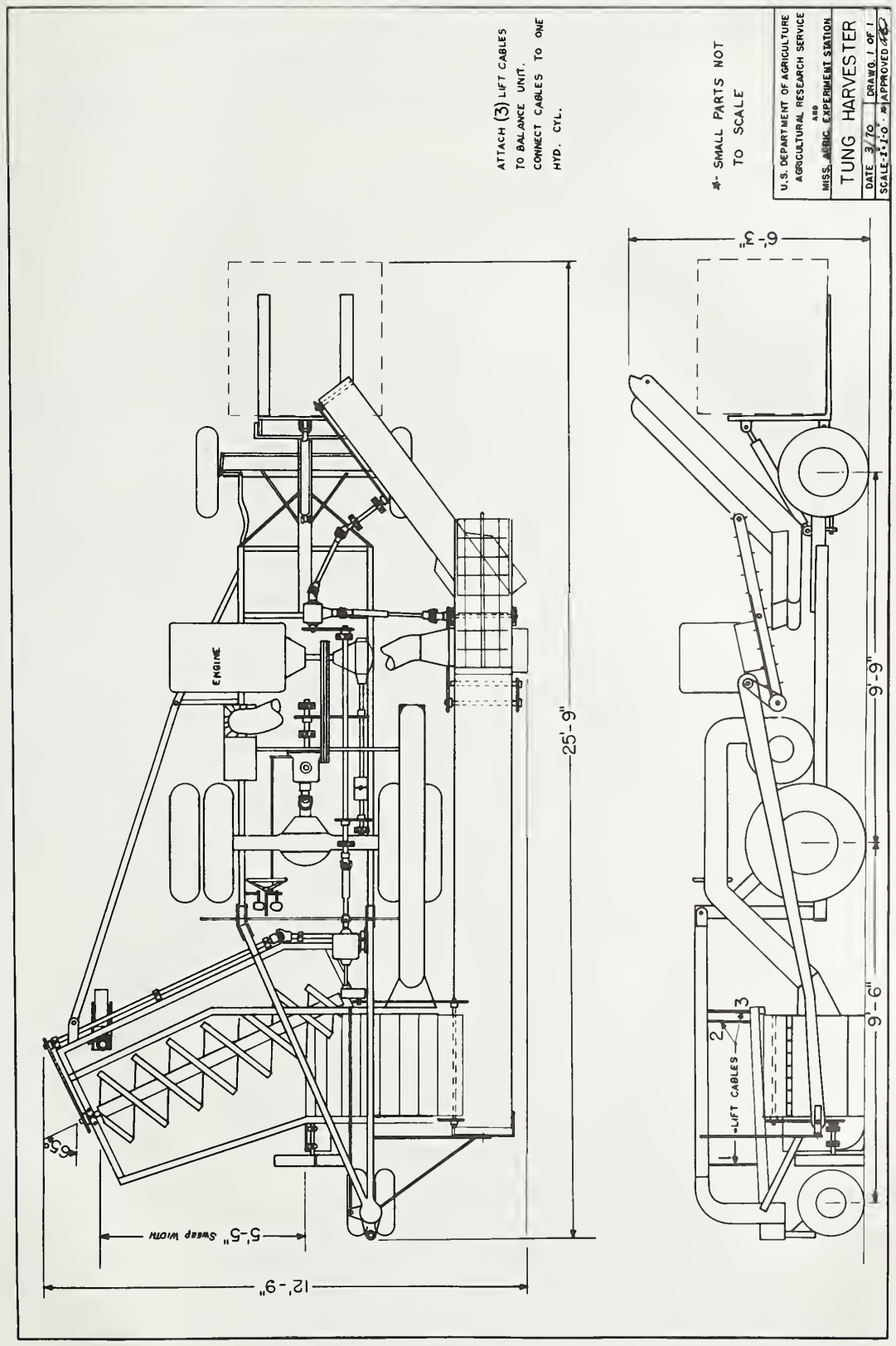

Figure 10.—Line sketch of the harvester showing the arrangements, basic dimensions, and a few of the critical details.

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